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Wind energy for rural areas of Algeria

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ABSTRACT

This paper presents long-term analysis of wind speed data in terms of annual, seasonal and diurnal variations at Tindouf, which is situated on the south west region of Algeria. The wind speed data was collected over a period of 08 years between 1976 and 1984. The study showed that the long-term seasonal wind speeds were found to be relatively higher during September compared to other months. The diurnal change in long-term mean wind speed indicated that higher electricity could be produced during 09:00–18:00 h, which also coincides with higher electricity demand period. The annual wind energy production and capacity factor, obtained using wind speed frequency distribution and wind power curve of 1000 kW wind turbine and RETScreen software were found comparable with each other if unadjusted energy production values calculated by the software were used rather than the renewable energy delivered. Development of wind farm of 30 MW installed capacity at this site could result into avoidance of 23,252 tonnes/year of CO_2 equivalents GHG from entering into the local atmosphere thus creating a clean and healthy atmosphere for local inhabitants.

Contents

1. Introduction

Wind energy has been used since the earliest civilization to grind grain, pump water from deep wells, and power sailboats. The increasing awareness of both the monetary and the environmental costs of burning fossil fuels is making alternative energy more appealing than ever. The power generated from wind can be used for all small and large applications such as lighting, refrigeration, computers, televisions, water pumping, water desalination, water heating, air-conditioning, running fans, and so on. A modern wind turbine of 1.65 MW rated capacity can produce more than 4.7 million kWh of energy in a year which will be enough to power more than 470 average households in the U.S. [1]. The power of the wind is clean, free, and abundance source of energy. It has no political and geographical boundaries and no need for means of transport. The wind power technology has achieved the commercial acceptability and is economically compatible with traditional means of energy generation.

These days, power of the wind is being encouraged due to availability of low maintenance multi megawatt sized efficient wind turbines. Accordingly, the annual global wind power market grew a staggering 41.5% in year 2009 compared to 2008. More than 38 GW of new wind power capacity was added around the globe in 2009 (see Fig. 1), bringing the total installed capacity to 158.5 GW [2].

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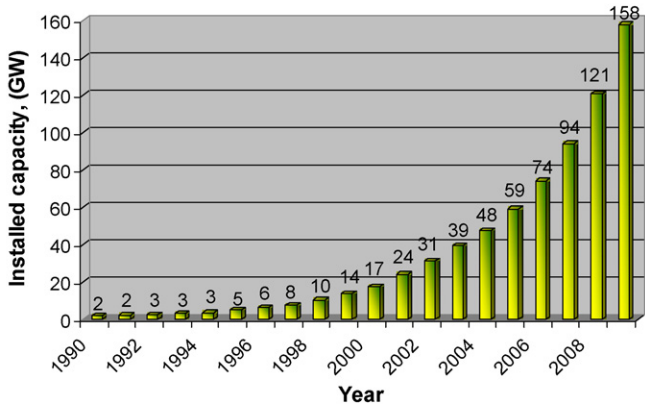

Fig. 1. Global wind power cumulative installed capacity.

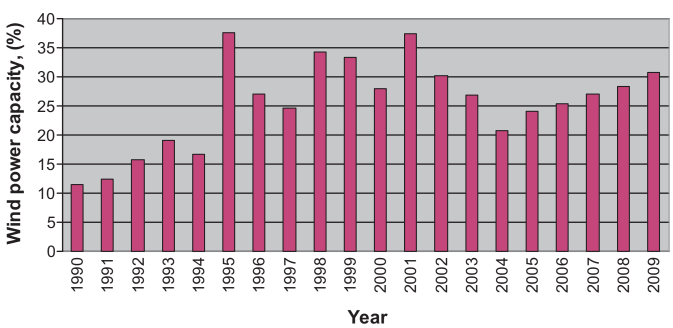

Fig. 2. Annual percent wind power installed capacity.

This represents a year-on-year growth of 31.7%, as can be seen from Fig. 2. One third of these additions were made in China, which doubled its installed capacity yet again. Since 2005, the global wind power growth has been always more than 25%.

The use of non renewable sources of energy not only results in deterioration of environment and health but also confronts us with the dilemma of the rapid depletion rates of such resources. While renewable energy sources can be used indefinitely with minimal impacts on the environment as compared with fossil fuels. Tremendous opportunities exist in Algeria for growth in the use of renewable energy technologies. The Algerian Government has introduced a national program for integration of renewable with an objective to achieve 5% of power generation by 2017 and a long-term target of reaching 20% by 2030. In Algeria the first wind speed measurement campaign was conducted in 1918. Wind measurements, however, were taken as an average of three readings in each day 07h00, 13h00 and 18h00. Averages were taken over each indicated hour, and the three hourly points were averaged to obtain the mean wind speed for that day [3] while the foremost work, in the form of wind atlas was reported by [4] giving the results of the statistical study of 37 locations using the WAsP. Himri et al. [5] utilized wind speed data over a period of almost 10 years for three stations, namely Adrar, Timimoun and Tindouf to assess the wind power potential at these sites. They estimated that wind farms of 30 MW installed capacity could be established at Adrar, Timimoun and Tindouf. These wind farms, if established, could produce 98,832 MWh, 78,138 MWh and 56,040 MWh of electricity annually, respectively. In another study, Himri and Himri [6] presented a review of Algeria's renewable energy sources, which could be exploited for the generation of sustainable energy in Algeria. Himri et al. [7] presented the wind characteristic at three locations in Algeria. They revealed that the energy could be harnessed for almost 64% the time using wind machines with cut-in speed of 3 m/s or more. Himri et al. [8] presented wind speed data analysis for three stations namely Adrar, Timimoun and Tindouf, Algeria, using wind energy conversion systems (WECSs) of different sizes between 150 and 1300 kW. They found that Adrar is the best location among the sites considered, for harnessing the wind power, while Timimoun is the second best location and Tindouf was placed at number three.

The higher capacity factors are also found for wind machines of smaller sizes. According to a contract signed lately between "Electricity and Gas Engineering Company" (CEEG) subsidiary of Group SONELGAZ "Algerian Company of Electricity and Gas" and French turbine manufacturer VERGNET, that the construction of Algeria's first wind firm, of 10 MW installed capacity consisting of 10 wind turbines of 1 MW rated power each from GEV HP, which will be based in the south-western region of Adrar (1543 km of Algiers), should be operational in 2012. The project would cost about €24 million in terms of total investment cost. Furthermore, the cost of energy from this wind farm is expected to be approximately €0.094/kWh. It is part of energy policy diversification in Algeria, a country that is fortunate in having large renewable energy resources and countless "Farwind" sites. Regarding the potentials of renewable energy and economic links with Europe, Algeria is among the most important country in North Africa.

Algeria is now positively disposed to the promotion of renewable energy source and views renewable as a way of promoting the development of small and local businesses in selected areas and diversifying supply patterns at the regional level. Algeria is perfectly placed to play a leading role in the lucrative future wind power industries. It has developed national programs and set national indicative targets for renewables in order to pursue the development of alternative electricity sources, with an objective to achieve 5% of power generation by 2017 and a long-term target of reaching 20% renewable energy power by 2030 [9].

This program establishes numerous measures to inquire and instruct the public about renewable energy. It is integrated into a framework for sustainable development and land use planning. The government has interpreted international examples of best practice (e.g. the German feed-in law for power generation based on renewable energy) into the policy framework of Algeria [10]. New Energy Algeria NEAL has joined the International Energy Agency's SolarPACES programs and incorporated renewable energy targets into national laws as shown in Table 1, to help create a stable environment for long-term investors.

Having ambitious quantitative targets, the Algerian's environmental friendly energy strategy has set up wind projects of total installed capacity of 36 MW around 2015. The total cost of the above installed capacity is expected to be around €82 millions.

Table 1
A total list of power production with wind power source up to 2015.

Project and place	Capacity (MW)	Bill-book	Cost ($ × 10^6)	Observation
WPP1.Tindouf	6	2006–2007	13	Wind power plant
WPP2.Tindouf	10	2008–2010	23	Wind power plant
WPP3.Timimoun	10	2010–2012	23	Wind power plant
WPP4.Bechar	10	2015	23	Wind power plant
Total	36	–	82	–

NEAL beside Government support has solicited several sources of funding to support these projects including World Bank, AIE and the European bank of investment [11]. In May 2010 an international workshop "the 2010 USTO Photovoltaic's Energy Workshop, Opportunities, Pathways and Solution" was held at the University of Sciences and Technology of Oran (USTO), Algeria.

The objective of the above workshop was to consolidate the construction and development of Sahara Solar Breeder (SSB) project which will be carried out on 500 m^2 in Saida (200 km of Oran). The estimated project cost of 5 million US$ is expected to be financed by a grant from the two Japanese agencies namely Japan International Cooperation Agency (JICA) and Japan Science and Technology Agency (JSTA) through the cooperation with USTO. Tindouf with an annual average wind speed of 4.3 m/s at 10 m above the ground surface may be a candidate site to start wind power generation in the near future [5].

This paper presents seasonal and diurnal variability of wind speed at 68.5 m above the ground and frequency distribution in different wind speed bins. The energy production and capacity factor, obtained using two methods viz. wind power curve of 1000 kW along with the frequency distribution and RETScreen software were compared.

2. Site and data description

Tindouf is located in the south west region of Algeria. The latitude and longitude of the location of data collection station are 27°40′ and 08°06′, respectively. It is 401 m above mean sea level. In order to develop wind power, it is important to understand the variability and availability of annual, seasonal and diurnal wind speed. At Tindouf, the wind speed measurements were made at 10 m AGL and recorded every 3 h interval (viz. 0, 3, 6, 9, 12, 15, 18 and 21 h). The data included in this study were collected over a period of 08 years from 1976 to 1984. With regard to general weather conditions, the average annual temperature was 21.8 °C and the surface pressure was 96 kPa. The annual average wind speed was found to be 4.3 m/s at 10 m AGL.

3. Analyses, results and discussions

This section provides in depth analysis of wind data, energy yield, capacity factor and comparison of capacity factor and energy yield with two methods.

3.1. Wind speed analysis

The seasonal variation of wind speed provides basic information about the wind strength and consequently about its availability during different months of the year which helps in planning the operation of existing power plants and the load requirements of the load center. The variation of monthly average wind speed at 10 m and 68.5 m above the ground is depicted in Fig. 3. As shown in Fig. 3, the maximum monthly mean wind speed of 5.5 m/s was observed in April, while a minimum of 3.0 m/s in December at 10 m AGL. Overall higher monthly mean wind speeds were observed during March–September compared to other months. At 68.5 m AGL, the hourly wind speeds were calculated using the 1/7th wind power law and the resulting monthly means over entire data collection period are also depicted in Fig. 3. It was observed that the estimated wind speed values at 68.5 m AGL followed the same trend as those of at 10 m AGL.

The diurnal variation of three hourly mean wind speeds at 10 m and 68.5 m heights is shown in Fig. 4. At 10 m height above the ground level, the higher values of hourly mean wind speed of the order of 4.4 m/s and greater were observed between 09:00 and 18:00 h while lower during rest of the period of the day. This observation indicates that higher electricity could be produced during 09:00 to 18:00 h which also coincide with higher electricity demand time. Similar trends, but with larger magnitudes, were noticed at 68.5 m AGL.

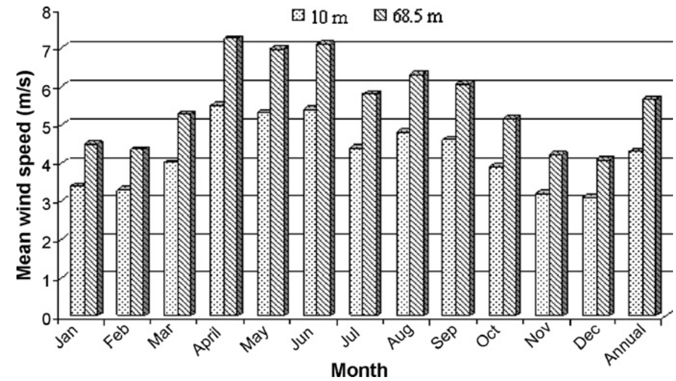

Fig. 3. Seasonal variation of long-term mean wind speed.

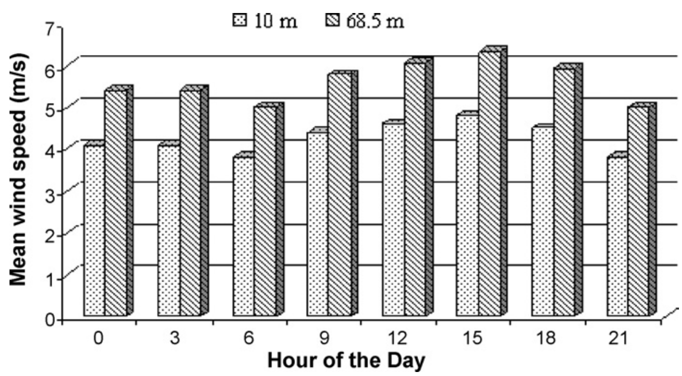

Fig. 4. Diurnal variation of long-term mean wind speed.

3.2. Wind speed frequency distribution

The wind availability analysis is carried out in terms of the occurrence of the number hours or percentage of time during which the wind remained in a certain wind speed bin. Fig. 5 shows the frequency distribution of wind speed in different wind speed bins at 68.5 m AGL at Tindouf.

The wind speed values at 68.5 m hub height were calculated using the 1/7th wind power law, it is also obvious from this figure that the wind remained above 3 m/s for 66% of the time, and usually

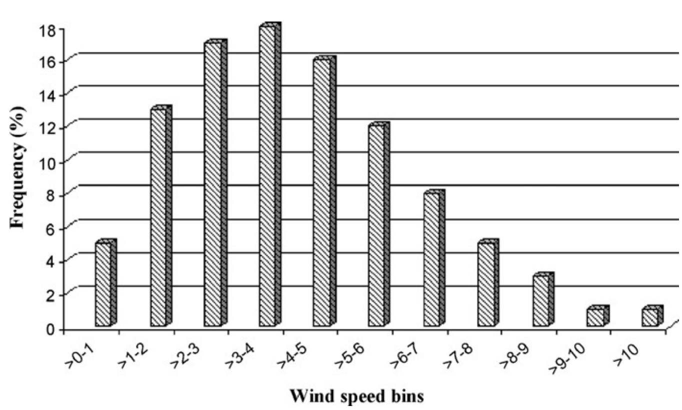

Fig. 5. Percent distribution of hourly mean wind speed in different bins for Tindouf at 68.5 m.

Table 2
Wind turbine parameters [20].

Item	Value
Model	DEWIND 62
Rated power (kW)	1000
Rotor diameter (m)	62
Hub height (m)	68.5
Swept area of rotor (m^2)	3019
Cut-in-wind speed (m/s)	3
Rated wind speed (m/s)	11.5
Cut-out-wind speed (m/s)	23
Rotor speed (rpm)	12.1–25.2
Tower type	Tubular

modern wind turbines start generating power at cut-in-speed of 3.5 or 4 m/s so the wind turbine can produce energy for 66% of the times at Tindouf.

3.3. Wind energy yield estimation

The energy yield was obtained using two different approaches viz., wind power curve of the wind machine along with the wind frequency distribution and the RETScreen software [12]. The RETScreen is a tool for analyzing the technical and financial viability of potential renewable energy projects is now being used by more than 35,000 people in over 196 countries around the globe, as reported in the literature [13–19]. The software requires the wind turbine power curve, the annual average wind speed; the rotor swept area, the mean temperature and pressure, hub height, etc. The wind turbine related parameters are summarized in Table 2 [5,20].

The wind power curve of the DEWIND 62 wind turbine, obtained from reference [20], is depicted in Fig. 6. Fig. 6 shows that wind turbine starts generating power at a cut-in-speed of 3 m/s and reaching to its rated capacity at 11.5 m/s and continues to produce rated power up to a wind speed of 16 m/s. At further higher wind speeds, the power yield decreases, as can be seen from Fig. 6. Fig. 7 shows the annual energy that can be generated using WECS of size 1000 kW and wind speed data at 68.5 m. It was noticed that at 68.5 m, the calculated annual energy was about 2213.3 MWh.

The plant capacity factor (PCF) of a wind energy conversion system was obtained by dividing the actual energy output during the year by the rated power and number of hours in a year. It is found that at 68.5 m, the PCF was about 25%. The various types of losses like array, airfoil soiling icing, down time and miscellaneous were also considered in the estimation of wind energy and are summarized in Table 3. The pressure and temperature adjustment coefficients which affect the energy yield were also taken into consideration, as listed in Table 3. A value of 0.143 for wind shear exponent was used to estimate the wind speed at the wind

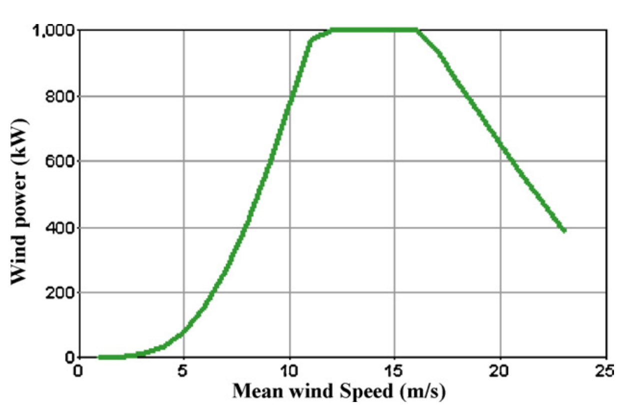

Fig. 6. Wind power curve of DeWind turbine DEWIND 62 [20].

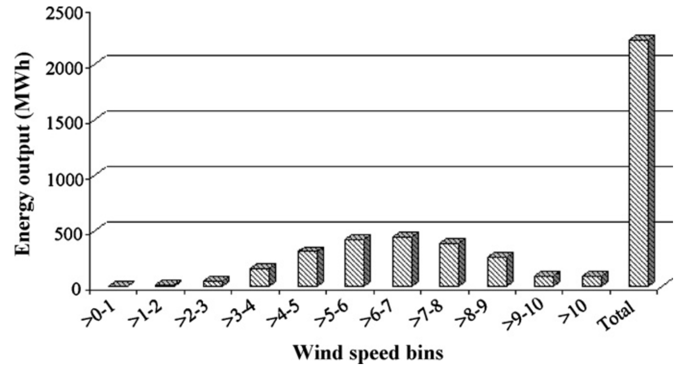

Fig. 7. Wind energy generated using WECS of 1000 kW for Tindouf at 68.5 m.

Table 3
Wind energy related coefficients used in energy yield estimation.

Item	Value
Array losses (%)	3
Airfoil soiling and/or icing losses (%)	2
Downtime losses (%)	2
Miscellaneous losses (%)	2
Pressure adjustment coefficient	0.95
Temperature adjustment coefficient	0.98
Wind shear exponent	0.14

Table 4
Summary of energy yield and related output from wind turbine DEWIND 62.

Item	Tindouf
Annual mean wind speed (m/s)	4.3
Gross energy yield (MWh/year)	1879
Wind energy delivered (MWh/year)	1716
Plant capacity factor (PCF) (%)	20
Green house gases (GHG) (tonnes/year)	775

turbine hub height. The wind energy yield and other relevant output parameters from the model are summarized in Table 4.

The annual gross energy yield, without losses, was 1879 MWh and the actual renewable energy delivered, which is the total annual energy produced by the wind machine after taking into count the effect of various losses like array, wake, airfoil soiling/icing, downtime, and miscellaneous, was found to be 1716 MWh each year, as given in Table 4. The plant capacity factor was found to be 20% at this site. Furthermore, the usage of wind energy at this site will avoid 775 tonnes of green house gases (GHGs) from entering into the local atmosphere of Tindouf each year and about 19,375 tonnes of GHG over the life time of the wind power plant.

Finally the energy yield values calculated from WPC and RETScreen were found to be distinct with each other for wind machine from DEWIND 62, since the RETScreen method resulted of almost 29% lower value of energy compared to other method (WPC) as summarized in Table 5.

The reason of difference between the energy values from two methods could be that RETScreen method takes into consideration various losses mentioned above while the WPC method reports the gross value. The comparison will be more meaningful if unadjusted

Table 5
Comparison of energy yield and plant capacity factor from 1000 kW WECS using two methods at 68.5 m height.

Item	WPC	RETScreen	Difference (%)
Wind energy delivered (MWh/year)	2213	1716	29
Plant capacity factor (PCF) (%)	25	20	25

energy yield (2018 MWh), which is the energy that one or more wind turbines will produce at standard conditions of temperature and atmospheric pressure. In such case the difference would narrow down to 9.6%.

4. Conclusion

The wind data analysis used in this paper covered a period of 08 years between 1976 and 1984. The study conducted a detailed analysis of the wind speed data and made the following observations:

- At Tindouf, the long-term annual mean wind speed at 68.5 m AGL, calculated using 1/7 power law, was found to be 5.7 m/s.
- The higher wind speeds were observed in the day time between 09:00 and 18:00 h and relatively lower during rest of the period.
- The long-term seasonal wind speeds were found to be relatively higher during March to September compared to other months.
- The frequency distribution of wind speed at 68.5 m AGL in different wind speed bins showed that the wind remained above 3 m/s for 66% of the time during entire data collection period. This means, that the energy could be harnessed for 66% of time using wind machine from DEWIND 62 with cut-in-speed of 3 m/s at Tindouf.
- The annual wind energy yield and plant capacity factor, obtained using wind power curve of 1000 kW and RETScreen methods were comparable with each other for unadjusted energy yield values rather than the renewable energy delivered.
- Wind farm of 30 MW installed capacity at Tindouf, if developed, could produce 51,467 MWh of electricity annually.
- The plant capacity factor at this site was found to be 20%.
- Such a development at this site could result into avoidance of 23,252 tonnes/year of CO_2 equivalents GHG from entering into the local atmosphere thus creating a clean and healthy atmosphere for local inhabitants.

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